Alterations In The Water Quality of Galveston Bay On A Time Scale of Decades

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As a project of the Galveston Bay National Estuary Program (GBNEP), we carried out a data compilation and analysis to determine long-term trends in water quality in Galveston Bay. Some of the results from this work have been summarized in previous State of the Bay symposia (e.g., Ward and Armstrong, 1993) and reported in excruciating detail in Ward and Armstrong (1992). This project acquired, digitized and compiled data from 26 historical and ongoing programs, dating back from some parameters, and sorted into two different segmentations: the 40 TNRCC water-quality segments, and 126 "hydrographic segments" whose boundaries reflect the flow and transport patterns within the bay. Each subset of data for a given segment comprises an independent set of data; each such set of data was subjected to a suite of statistical analyses. Exclusive of special-purpose analyses and derived parameters (such as dissolved oxygen deficit), we performed (73+50) x (40+126) = over 20,000 independent statistical evaluations, which represents a new level of achievement in self-flagellation.

The above-cited references present at length the distribution of water and sediment quality in the system and proffer hypotheses about the controls governing those distributions. In the present paper, we focus on the alterations in water quality as revealed by a time-trend analysis of this data. Briefly, the long-term trend was determined as the slope of the linear regression for each of the hydrographic segments. As there is substantial fluctuation about such a trend line, due to imprecision and kinetics that affect concentrations of waterborne parameters, we also delineated the confidence bounds on the trend line. An example is presented in Fig. 1, for near-surface salinity, in which the computed trend for each segment is indicated to be increasing, indeterminate, or decreasing, according to the 95% ("probable") or 80% ("possible") confidence bounds on the slope. A summary of the conclusions about long-term trends of the more important water-quality indicators is given in Table 1.

Some of the more puzzling trends are in the physical parameters, temperature, salinity and suspended solids. The magnitudes of these trends, Table 1, are not trivial; these are substantial, big-time alterations in these parameters. The decline in suspended solids represents a decrease of average concentrations by a factor of two in two decades. In Ward and Armstrong (1992), several hypotheses were floated as to the mechanism of this decrease. At that time, we thought the more likely explanation was response to a modification in exogenous sources, such as river loading, waste treatment, and altered land use. Since then, the same kinds of analyses have been carried out for the Coastal Bend bays (Ward and Armstrong, 1997), and the same decline in suspended solids and turbidity was

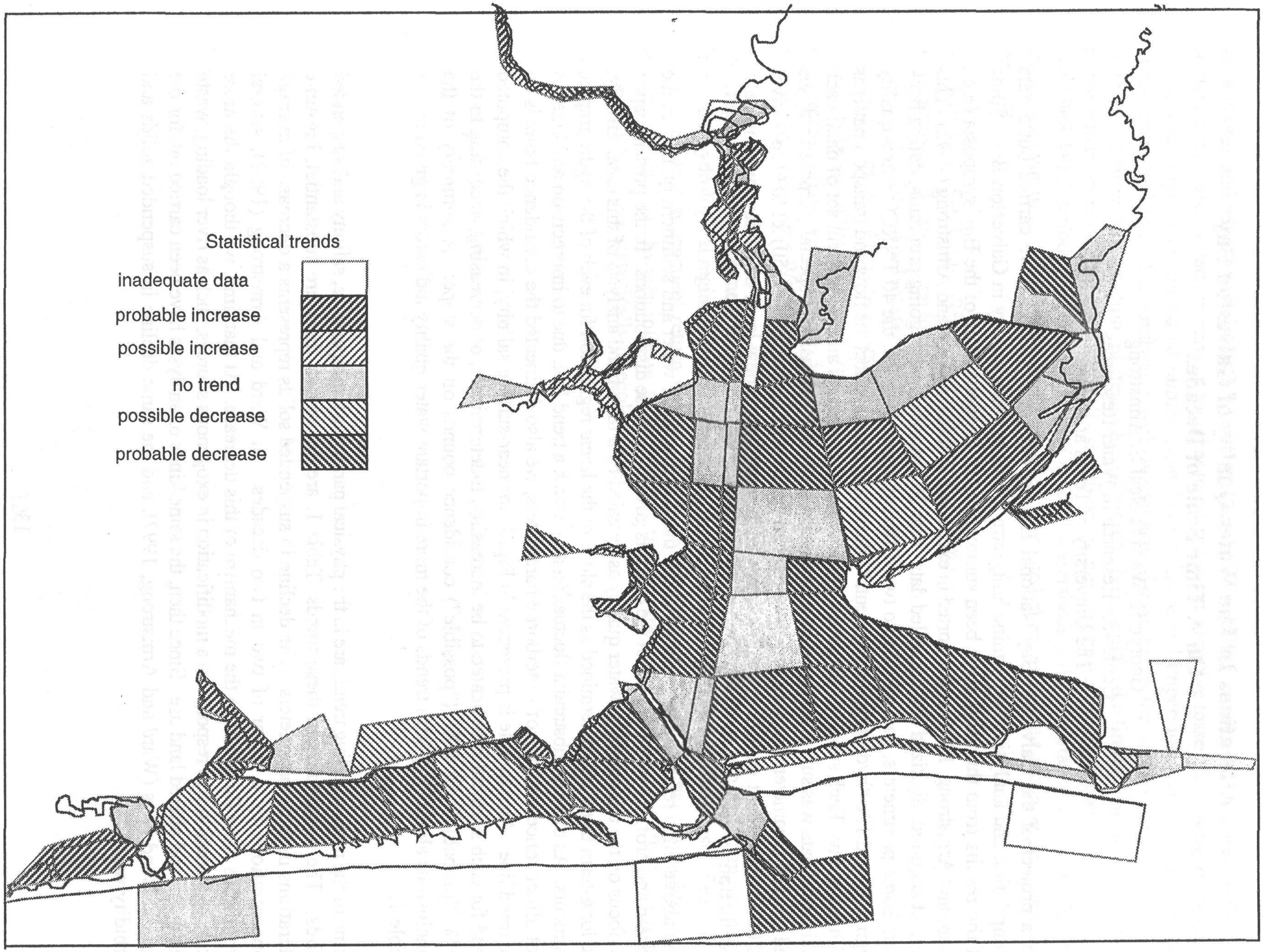

Fig. 1 - Statistical trends of salinity (WQSAL) within upper 1.5 m in Galveston Bay (Ward & Armstrong, 1992)

Table 1
Long-term trends in key water-quality indicators,
from Ward and Armstrong (1992)

parameter	***trend***	***rate***
temperature	declining	0.06°C/yr
salinity	declining	0.2 ppt/yr
DO deficit	declining in HSC increasing in areas of open	
suspended solids	declining	2.1 ppm/yr
inorganic nitrogen	generally declining in open bay	
phosphorus	declining	0.043 ppm/yr
TOC	declining	0.50 ppm/yr
chlorophyll-a	declining	1.7 ppb/yr
metals	generally declining	

discovered, but these bays have generally not had the same level of watershed and waste-treatment alterations as the Galveston system. These results suggest that endogenous sources, such as remobilization from the bed or shoreline erosion, may be more important.

The decline in temperature was thought to be due to either altered exchange with the Gulf of Mexico or long-term climitological changes. Some recent work by Kim and North (1995) adds support to this latter possibility. This has been further reinforced by detection of the same declining trend in the Coastal Bend bays (Ward and Armstrong, 1997). While this decline is not likely to pose any serious threat to the water quality or habitat of Galveston Bay, a decline of such a large magnitude in a parameter which we would expect to exhibit long-term stability cried for an explanation.

One of the more significant, and surprising, results of the study was the declining trend in salinity. This is a decline in average salinity on the order of 5 ppt over the last three decades. This is over twice the alteration (and in the opposite direction) projected to occur with the planned enlargement of the Houston Ship Channel. There is no direct coorelation with freshwater inflow. In fact, there are really no long-term trends in freshwater inflow over this period (see the report by Gary Powell in this symposium); certainly not of the order necessary to effect a decline in salinity this large. Although several hypotheses were proposed in the GBNEP report, at present we cannot explain the source of this time trend. This is discomforting. Prediction of salinity is one of the fundamental requisites for modeling the bay. Yet we are presently incapable of modeling the observed long-term change. (In the Coastal Bend bays, an increase in salinity was determined in the upper bays-Copano, Aransas, and Nueces- and seems to be well correlated with a long-term decrease in inflow, Ward and Armstrong, 1997.)

Compilation of such a long-period record of salinities offers the possibility of applying modern time-series analyses to examine temporal patterns in salinity. Some preliminary work along this line has been carried out using this data base (Lee et al., 1997), supplemented by the 40-year record of salinities at Pleasure Pier, obtained by the National Ocean Service.* This has included spectral analyses and autoregressive moving average (ARMA) modeling. For the few readers that may care about such matters, the fact that salinity data is taken at irregular intervals posed a great computational difficulty in this work: 99.9999% of existing techniques for discrete Fourier or time-series methods assume an equal sampling interval; therefore we had to devise methods for correct treatment of this data, see Lee (1997). Fig 2 is an information-dense example of results of this work.

The GBNEP data set offers the first real opportunity to quantify long term periodicities in the variation of salinity. Why would people do such a thing?

(1) Exposing such periodicities can provide insight into casual controls on salinity, therefore some of its basic physics;

(2) Long-term periodic tendencies may explain shorter-term alterations as partial-cycle responses;

(3) Such analyses, especially of impulse-response behavior, provide new validation;

(4) Long-term analyses can provide some indication of how long a data set is necessary to reliably infer a trend;

(5) Insight may be obtained into the long-term behavior of other elements of the bay that depend upon salinity.

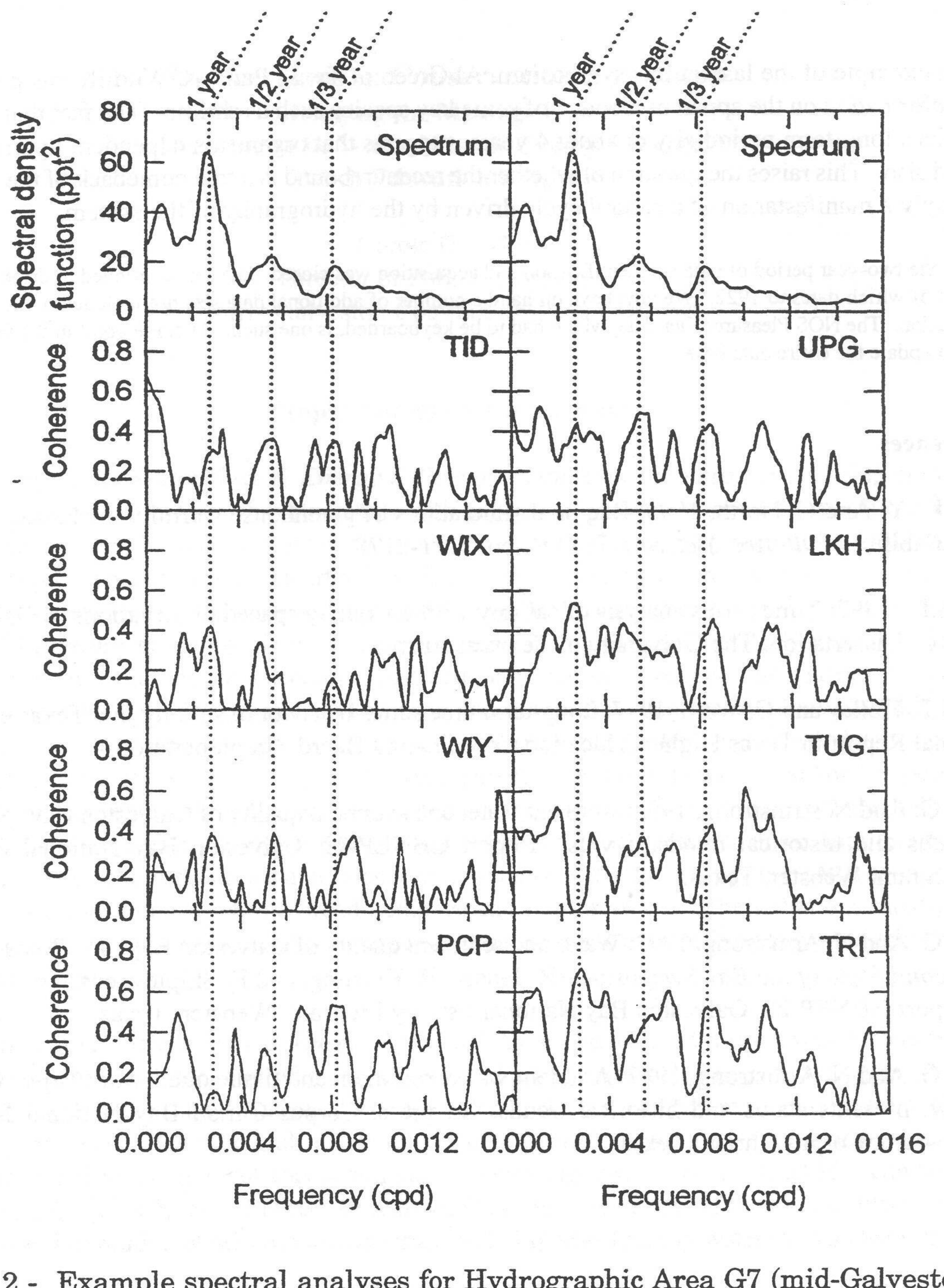

Figure 2 - Example spectral analyses for Hydrographic Area G7 (mid-Galveston Bay). Top panel: frequency spectrum of near-surface salinity. Other panels: spectral coherence with: water level (TID), longshore component of wind (WIX), component of wind normal to shoreline (WIY), flow of Trinity River at Romayor (TRI), combined gauged flow into upper Galveston Bay (UPG), precipitation on bay periphery (PCP), Lake Houston discharge (LKH), estimated ungauged flow on Trinity watershed (TUG).

As an example of the last, at this symposium, Al Green of Texas Parks & Wildlife has presented new information on the apparent rebound of some key species such as shrimp. The fact that salinity exhibits a long-term periodicity of about 4 years, suggests that organisms dependent upon salinity should also. This raises the question of whether the recent rebound is a true comeback of the fishery, or simply a manifestation of a natural cycle driven by the hydrography of the system.

* After the two-year period of data set identification and acquisition was closed, data sets continued to dribble in, the earliest of which dates to 1922. We now have on hand a number of additional data sets not included in the GBNEP compilation. The NOS Pleasures Pier data, which had to be keyboarded, is one such. At some point in the future, we hope to update the entire data base.

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